Volatility Spillover in India, USA and Japan Investigation of Recession Effects

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Abstract

In the past decades, there has been an unprecedented increase in cross border transactions between countries in terms of goods and financial flows. This integration has been fuelled by search of lower risk investments, risk diversification, search for cost effective and more efficient factors of production and dreams of global dominance in the world wide market place. An important result of these capital flows was its impact on linkages of global asset returns and spillover of volatility from one capital market to another. This study aims to understand the spillover effect between the US, the Japan capital markets and Indian equity index (Sensex). We analyze whether the volatility spillover is contemporaneous (directly in the very same day), or dynamic/lagged (with one day lag). A GARCH (1,1) model of modelling volatility has been undertaken for this purpose. This paper concludes that contemporary volatility of the Japan capital markets influenced Sensex in the pre-recession period but in the post recession there was no significant contemporaneous spillover from USA and Japan capital markets to Sensex. However, US became a significant factor while considering dynamic spillover in the post recession era. Also, there was no bidirectional volatility spillover from India to US. But, the study showed evidence of dynamic volatility spillover from Indian market to Japanese Capital market.

Introduction

Capital market linkages and Volatility Spill-over

In the past decades, there has been an unprecedented increase in cross border transactions between countries in terms of goods and financial flows. This integration has been fuelled by search of lower risk investments, risk diversification, search for cost effective and more efficient factors of production and dreams of global dominance in the world wide market place. This integration has been gaining momentum because of gradual lifting of restrictions on capital flows and relaxation of exchange control in many countries. Advances in computer technology, telecommunications and transportation have also expedited international financial flows.

An important result of these capital flows was its impact on linkages of global asset returns. With freer flows, market became more closely connected. These linkages were evident during stressful market events, such as the International Crash of October 1987, European Currency Crisis in 1992, the Asian flu in 1997, the Russian Government's default and the collapse of LTCM in 1998, and the recent subprime crisis of 2007, when stock markets around the world experienced abrupt downfalls.

These simultaneous downfalls in markets across the world generated academic and industry interest in understanding the correlations between the global equity markets and several researchers have examined the degree of interdependence among the world's major equity markets. Two main approaches to analyze interdependence can be recognized from the literature. The first approach is to examine various aspects of market interdependence using cointegration and causality. The second approach is to examine interdependence in terms of volatility spillover.

Research on the transmission mechanism of volatility between stock markets has been advancing rather rapidly since the seminal work of Engle (1982) who introduced the ARCH model. For example, Hamao *et al* (1990) studied first and second moment interdependencies in New York, Tokyo, and London during the 1987 crash using univariate Generalized Autoregressive Conditional Hetroskdasticity (GARCH) models. They found that volatilities coming from New York and London influence volatility in Tokyo and London. Lin, Engle, and Ito (1991) examined the interaction of the US and Japanese stock markets in terms of mean and volatility and found that the two markets influence each other.

USA and Japan capital markets have been established as two of the most influential capital markets in the world through various researches. In 2008, crash in USA and Japan capital market was followed by crashes in other capital markets throughout the world. During that time, Sensex (Bombay stock Exchange Benchmark) recorded loss of 74%. On the other hand, in 2006 and 2007, Sensex gave return of respectively 38% and 37%. But with financial crisis caused by subprime mortgage in USA, Sensex fell continuously.

As discussed before, capital market volatility has been the focus of many researches. Generally, these researches have focused on researching volatility in USA and Japan capital market. However, there is no research for volatility spillover between the Indian capital markets with some major capital markets in the world.

Research by Hamao, Masulis, and Ng (1990) found that there is significant spillover effect from USA and UK capital markets to Japan. Balasubramanyan and Premaratne (2003) concluded there is small but significant volatility spillover from Singapore capital market to USA, Hong Kong, and Japan. Their research is interesting because many of previous researches tend to conclude spillover effect would be significant from dominant market to smaller, and the effect would be unidirectional.

Volatility research in Indian capital market with some of major capital markets in the world is important, in order to find out how much movement in another capital markets could impacted Indian capital market. We should also analyze whether the volatility spillover is contemporaneous (directly in the very same day), or dynamic/lagged (with one day lag). This should be our attention because the trading time difference between the capital markets (in this instance India, USA, and Japan) will be important in analyzing the types of volatility spillover.

This paper contributes to the existing literature in two ways. First, this paper attempts to investigate the contemporaneous and dynamic volatility spillover effects between Indian capital market and two of the most influential capital markets in the world, USA and Japan. It is intuitive to assume only unidirectional impact to exist from

USA and Japan, but this paper will show that this is not the case always. Second, this paper examines the impact if recession as a structural change in these capital markets in terms of volatility spillover. It is intuitive to assume that after recession, resilient emerging markets such as India would impact unstable USA and Japan capital markets in a different manner as there has been lot more capital inflow into India post recession. This paper will show how this structural change is evident in volatility spillover effects between these three capital markets.

The Generalized Autoregressive Conditional Hetroscedasticity (GARCH) model introduced by Engle (1982) and Bollerslev (1986) has been used to model volatility. The results are based on daily price observations from January 2005 to December 2009 and have been separated into two periods of January 2005 to December 2007 and January 2008 to December 2009 to investigate any changes in behaviour of volatility spillover mechanism if it exists.

The paper is divided into five sections. The second section provides the literature review in the area of volatility spillover research. The third section illustrates the data used and the econometric model used to compute volatility spillover effects. The fourth section provides insights into the relationship between the volatilities and extent of volatility spillover between each capital market pair. In the fifth section, the conclusion of the work is presented.

Literature Review

Impact of globalization on region market integration

There is a diverse amount of literature on the stock market integration and information spillover (both in terms of return and volatility) across the markets. Some studies have examined only the return spillover across the markets, while some other studies consider both the first and the second moments of equity prices to examine the cross border spillover. Apart from examining only the presence of such interdependence among the equity markets, some authors have also focused on the impact of some special events such as market crisis, market liberalization etc. on the spillover of information across the national borders. All the above studies aimed at examining only the spillover of information among the national equity markets, but there are also some studies that focused on the possible factors or in short, the determinants of such information spillover among different markets (Mukherjee & Mishra, 2008).

Increasingly regional economic activity and financial market liberalization since 1980s resulted in integration of regional economies all over the world. Globalization also allowed an enterprise in one country to sell its stock in another country as new source for raising its capital needs for its expansion. This expansion was further helped by fast paced development in communication and information technology. This made it possible for local markets to achieve an international scale.

With these conditions, globalization and expansion of financial markets resulted in growth of financial market integration. Integration of financial markets, especially in capital markets, resulted in a correlation between return and volatility of every capital market. This happened because globalization not only meant cross border trading in securities buy also investments on an internationals scale. Hence, any changes in the fundamentals of an economy impacted both the domestic market and the foreign markets.

Another reason for change of price stock correlation between two counties is contagion. Contagion is change of stock's price in a country because of impact from another country that is not caused from fundamental economy of the other country. The classic example of this market contagion is downfall of New York Stock Exchange in October 1987, famously known as Black Monday, causing downturn stock price in the world.

Volatility

Globalization and multi-directional flow of capital between financial markets increase market interdependency. There are many empirical studies which conclude that there exist comovements and interdependency between capital markets in some countries. There are two approaches used to research it. The first approach is researching many aspects of market interdependency using cointegration and causality. One research using this first approach is research by Eun and Shim (1989). The second approach is researching interdependency concerning in volatility spillover. Hamao, Masulis, and Ng (1990) used this approach.

According to King and Wadhwani (1990), an investor in capital market uses announcement or information that accumulated from last closing of domestic capital market for estimating its impact on opening price. Otherwise, they can also use change of price from global capital market which opens earlier than domestic capital market to estimate its impact probability on domestic capital market.

According to Calvet, Fischer, and Thompson (2004), main objective in research of volatility spillover is to understand how volatility can affect return of portfolio. Return of portfolio has implication on daily risk management, portfolio selection, and derivative price. Also, Rigobon and Sack (2003) argued that price of assets are intertwined each other and analyzing a single market without paying attention to another aspect would means ignoring important information of market behaviour. Change of asset's price in its market not only impacted by volatility shock, but also by its reaction to shock on asset's price in different country.

In this research there will be two terminologies on volatility: contemporaneous volatility spillover and dynamic volatility spillover. Contemporaneous volatility spillover is volatility spillover in the very same day. Contemporaneous volatility spillover generally happened on stock markets in a same region. This can be explained by the fact that capital markets in one region have overlapping trading time. So, information from one capital market is transmitted to another capital market on the same day where trading is still taking place. Based on information from one capital market, investor could make a decision that will impact the other capital market.

Meanwhile, dynamic volatility spillover generally happens between capital markets in different regions. In such a scenario one capital market starts trading when the other is closed or almost closing. In this circumstance information from one capital market will make an impact on the other capital market on the next trading day, so volatility spillover happens on the next day. This phenomenon is what is called dynamic volatility spillover

Previous Research on volatility spillover

Some previous researches showed the existence of volatility spillover. Eun and Shim (1989) analyzed daily return in Australia, Hong Kong, Japan, France, Canada, Switzerland, Germany, USA, and UK capital market. They found a substantial interdependence between each market with USA capital market being the most influential. For any changes in USA, all European and Asia Pacific markets showed high responsiveness with one day lag. Most of this response to the shock took place within two days.

Hamao, Masulis, and Ng (1990) used daily and intraday data from Japan (Nikkei 225), UK (FTSE 100), and USA (S&P 500) for three years (from April 1985 to March 1988). They researched price interdependency and volatility between these three capital markets. In this research, returns were calculated by comparing closing price with opening price, and opening price with closing price. Their research used GARCHM (1,1) model. The result concludes that there is significant spillover effect from USA and UK capital market to Japan, but there is no significant spillover effect from Japan capital market to USA and UK.

Park and Fatemi (1993) researched relation between capital market of Basin Pacific countries with USA, UK, and Japan. They concluded that USA capital market is the most influential compared to UK and Japan. From their research they found that Australia is the most sensitive to USA market. Singapore, Hong Kong, and New Zealand form the next group showing moderate relation to those markets. Meanwhile, Korea, Taiwan, and Thailand showed little impact from those markets. Basin Pacific economy has unique structure that as most countries have emerging capital markets and its stock fluctuation is mostly affected by domestic factors.

Lin, Engle, and Ito (1994) researched how return and volatility of Japan and USA indices correlated one another. Data used in that research is intraday data from Nikkei 225 and S&P 500. They used daytime return (opening price to closing price) and overtime return (closing price from previous day to opening price). Daytime and overtime return data was also used by Hamao, Masulis, and Ng (1990), who found that foreign daytime return affected domestic overnight return significantly.

Often it is said that USA capital market impacted to Japan, not vice versa. However, the research by Lin, Engle, and Ito showed that return and volatility market interdependency is bidirectional between Japan and USA.

Janakiramanan and Lamba (1998) researched the empirical relation between Basin Pacific capital markets. Their result showed USA capital market influenced all capital markets but Indonesia, the isolated one. Markets with similar geographic and economic structure showed significant impact one another. Overall, impact from USA market to Australia-Asia market has decline significantly nowadays, and Indonesia is most integrated to these markets.

Indrawati (2002) used VAR and VEC model with GNC to test dynamic relation of macro monetary economic variable and capital market indices. Her research showed Indonesian capital market integrated to USA capital market and concluded 1% increased in USA capital market will affected increase of Indonesian Composite Index as 0.32%. From the research it can also be concluded that there is Granger cause bidirectional relation between Indonesia capital market with Thailand, Taiwan, and South Korea capital market. Besides, all stock markets in her research (Indonesia, Thailand, Taiwan, and South Korea) were integrated with USA capital market.

Balasubramanan and Premaratne (2003) researched volatility spillover and comovements by using daily return data from January 1992 to August 2002 for Singapore stock exchange with USA, UK, Hong Kong, and Japan. One interesting result from their research is there is significant volatility spillover from Singapore capital market to Hong Kong, Japan, and USA. We know in case of influence and market dominance, Hong Kong, Japan, and USA capital markets are far more influential and dominant to Singapore capital market. Many researchers tend to conclude that spillover effect will be significant from dominant market to smaller market, in a unidirectional way. Thus it is interesting to note that there is little but significant volatility spillover from Singapore to Hong Kong, Japan, and USA.

Kupiec (1991) researched stock market return volatility correlations among 15 OECD countries and concluded that the average pair wise correlation among these 15 countries' stock returns increased over 50 percent between the first and the second half of the 1980s. An examination of the individual correlation estimates indicates that the correlations between G7 countries' indices became measurably stronger earlier, whereas the correlations among the non-G7 country indices increased for the most part during the late 1980s. The estimated correlation changes for the 1980s indicate that, for the G7 markets, returns have become only slightly more positively correlated over the period whereas for the other markets, return correlations have increased more substantially. The estimates show that volatilities, particularly among the major markets, were much more strongly positively correlated in the second half of the 1980s as compared with the first half of the decade.

By using the VAR method, Cheung and Cha (1998) empirically investigated the relationships between the four Asian emerging markets: Hong Kong, Korea, Singapore and Taiwan, and the two largest markets in the world: U.S. and Japan. They found that the four AEMs react differently to the price movements in the U.S. and the Japanese markets. They concluded that the U.S. plays an important role in leading other equity markets. Their research shows that while most of forecast error variance of the return rates in these markets is explained by domestic own innovations, U.S. and Japanese innovations have more explanatory power in Hong Kong and Singapore than in Korea and Taiwan. This foreign effect is pronounced after the Crash of the October 1987, especially in Singapore. The results show that the U.S. market affects the Hong Kong and the Singapore markets, but not the Korean and the Taiwanese markets while the Japanese market has little impact except on the Korean market.

Piero, Quesada and Uriel (1998) have investigated the relationships between daily returns in the New York, Tokyo and Frankfurt stock markets, from January, 1990 to September, 1993. They found New York to be the most influential market, with an influence ability that almost doubles that of Tokyo and triples that of Frankfurt. On the other hand, Tokyo was found to be the most sensitive market, with a level of sensitivity that more than doubles that of New York, with Frankfurt between the two.

Baele (2003) concluded that for nearly all European equity markets countries, the probability of a high EU and US shock spillover intensity has increased significantly over the 1980s and 1990s, even though the increase is more pronounced for the sensitivity to EU shocks. In fact, in many countries, the sensitivity to EU shocks dropped considerably after 1999. The research shows that, EU shocks explain about 15 percent of local variance, compared to 20 percent for US shocks and that while the US – as a proxy for the world market - continues to be the dominating influence in European equity markets, the importance of the regional European market is rising considerably.

Following the ARCH family of statistical models, Hamao (1990), Christofi (1999), Kim (2005), Wang (2005), Baur and Jung (2006) etc. have examined the volatility spillover among the developed and emerging European, American, and Asian equity markets with the US. Most of the studies have shown a unidirectional volatility spillover from the US to other country. Abraham and Seyyed (2006) have examined the flow of information among the Gulf equity markets of Saudi Arabia and Bahrain and have interestingly found an asymmetric spillover of volatility from the smaller but accessible Bahraini market to the larger but less accessible Saudi market.

Though there is a vast amount of literature on the spillover of information across the markets, only a few of them have focused on the Indian equity market. Kumar (2002), Nath (2003), Mukherjee (2005), Wang (2005) etc. are some of the studies where Indian equity market has been treated as one of the market the price and volatility of which affects and also is affected by the price and volatility of other markets. By carrying a comprehensive analysis from correlation to Granger causality and then to application of GARCH models to examine the comovement and volatility transmission between US and Indian stock markets, Kumar (2002) have found Significant return and volatility spillover from US to India. Nath (2003) have examined the interdependence of the three major stock markets in South Asia, viz. India, Singapore and Taiwan and have find out no cointegration between the stock market indices during the entire study period. By applying the Granger causality test and the Geweke measure of feedback, Mukherjee (2005) have examined the stock market inter-linkages (in terms of returns) among India and the world equity markets. Wang (2005) have examined the return and volatility spillover from US and Japan to three South-East Asian capital market viz. India, Pakistan and Sri Lanka. Though they have found a return spillover from US and Japan to all the three markets, there is a significant volatility spillover from US to India and Sri Lanka and from Japan to Pakistan.

Mukherjee and Mishra (2008) conclude that apart from different degrees of correlations, both in terms of returns and volatility of returns, among Indian equity index viz. SENSEX with that of twelve other Asian countries, there is a significantly positive and bi-directional contemporaneous intraday (open-to close) return spillover among India and almost all the foreign countries except only with Sri Lanka. But unlike contemporaneous spillover, transmission of information lagged by one day, alternatively dynamic intraday spillover among India and its major Asian counterparts are not found to be stronger, especially in one direction, i.e. from other Asian countries to India. These facts clearly suggest that the information generated in Indian market gets transferred into other Asian markets not only on the same day but also in the next day.

Mulyadi (2009) conclude that Volatility of Indonesia capital market is influenced from both USA and Japan capital markets. Both contemporaneous volatility spillover and dynamic volatility spillover from USA capital market are significant in 1%. With Japan capital market, the contemporaneous and dynamic volatility spillovers are significant. Dynamic volatility spillover between Indonesia and Japan can be explain as there is market imperfection so information from foreign capital market impacted domestic capital market on the next day. On testing the existence of bidirectional volatility spillover it was found that with USA capital market there is no bidirectional volatility spillover. Meanwhile, with Japan capital market there is significant bidirectional volatility spillover.

Methodology

Data Used

Data used in this research is closing price of indices. Daily return data $t\,y$ calculated using following formula:

$$R_{i,t} = 100 * Ln(\frac{P_{i,t}}{P_{i,t-1}})$$

Data of indices obtained from Yahoo! Finance from period January 1st, 2005 to December 31st, 2009. Usage of daily data cause of daily return can capture all possible interaction. Meanwhile, using weekly or monthly data could delete possible interaction that taking place only for several days. Data used are indices of each country, Sensex for India, S&P 500 index for USA, and Nikkei 225 for Japan.

For volatility standard deviation of past 50 days of the returns on all the indices has been computed.

Econometric Model

With objective to obtain information about volatility spillover from time series data, we used GARCH (1,1) model in this research. GARCH model is the accurate model for volatility as the error terms in the return time series show heteroskedastic behaviour. This means that, the variance of the error terms is not constant for these time series.

$$var\left(\varepsilon_{i,t}\right) \neq constant$$

We use basic GARCH model for proxy volatility. Following model estimated using Maximum Likelihood Procedure applying BHHH algorithm. The following are models used to test contemporaneous spillover:

$$R_{i,t} = \gamma_0 + \gamma_1 R_{i,t-1} + \gamma_2 R_{j,t} + \gamma_3 h_{j,t} + \varepsilon_{i,t} \quad (1)$$

$$h_{i,t} = \alpha_0 + \alpha_1 \varepsilon_{i,t-1}^2 + \alpha_2 h_{i,t-1} + \delta_1 h_{j,t} \quad (2)$$

$$R_{j,t} = \theta_0 + \theta_1 R_{j,t-1} + \theta_2 R_{i,t} + \theta_3 h_{i,t} + \varepsilon_{j,t} \quad (3)$$

$$h_{j,t} = \beta_0 + \beta_1 \varepsilon_{j,t-1}^2 + \beta_2 h_{j,t-1} + \Phi_1 h_{i,t} \quad (4)$$

$R_{i,t}$: Return of domestic capital market at t period

$R_{i,t-1}$: Return of domestic capital market at t-1 period

$R_{j,t}$: Return of foreign capital market at t period

$R_{j,t-1}$: Return of domestic capital market at t-1 period

$h_{i,t}$: Volatility of domestic capital market at t period

$h_{i,t-1}$: Volatility of domestic capital market at t-1 period

$h_{j,t}$: Volatility of foreign capital market at t period

$h_{j,t-1}$: Volatility of foreign capital market at t-1 period

$\varepsilon_{i,t}$: Error of domestic capital market at t period

$\varepsilon_{j,t}$: Error of foreign capital market at t period

From above model we can see that $R_{j,t}$ and $h_{j,t}$ are contemporaneous spillover variable from foreign capital market (another country). Meanwhile, models used to test dynamic spillover are:

$$R_{i,t} = \eta_0 + \eta_1 R_{i,t-1} + \eta_2 R_{j,t-1} + \eta_3 h_{j,t-1} + \varepsilon_{i,t} \quad (5)$$

$$h_{i,t} = \chi_0 + \chi_1 \varepsilon_{i,t-1}^2 + \chi_2 h_{i,t-1} + \omega_1 h_{j,t-1} \quad (6)$$

$$R_{j,t} = \psi_0 + \psi_1 R_{j,t-1} + \psi_2 R_{i,t-1} + \psi_3 h_{i,t-1} + \varepsilon_{j,t} \quad (7)$$

$$h_{j,t} = \xi_0 + \xi_1 \varepsilon_{j,t-1}^2 + \xi_2 h_{i,t-1} + \rho_1 h_{j,t-1} \quad (8)$$

$R_{i,t}$: Return of domestic capital market at t period

$R_{i,t-1}$: Return of domestic capital market at t-1 period

$R_{j,t-1}$: Return of foreign capital market at t-1 period

$R_{j,t-1}$: Return of domestic capital market at t-1 period

$h_{i,t}$: Volatility of domestic capital market at t period

$h_{i,t-1}$: Volatility of domestic capital market at t-1 period

$h_{j,t-1}$: Volatility of foreign capital market at t-1 period

$\varepsilon_{i,t}$: Error of domestic capital market at t period

$\varepsilon_{j,t}$: Error of foreign capital market at t period

This research tests both contemporaneous and dynamic volatility spillover. Testing of dynamic volatility spillover because of there is one day lag between USA and either Indonesia or Japan. In table 1, we can see trading time of three capital markets. Japan capital market is the first market to be open for trading. Then, we can see overlapping trading time between India and Japan. Trading in USA market takes place after India and Japan.

Table 1: Table of trading time on the Indian, Japanese and US capital markets

Japan (from 00:00 - 06:00)											
			India (from 06:30- 12:00)								
							USA (from 14:30-21:00)				
00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00

Graphical Analysis

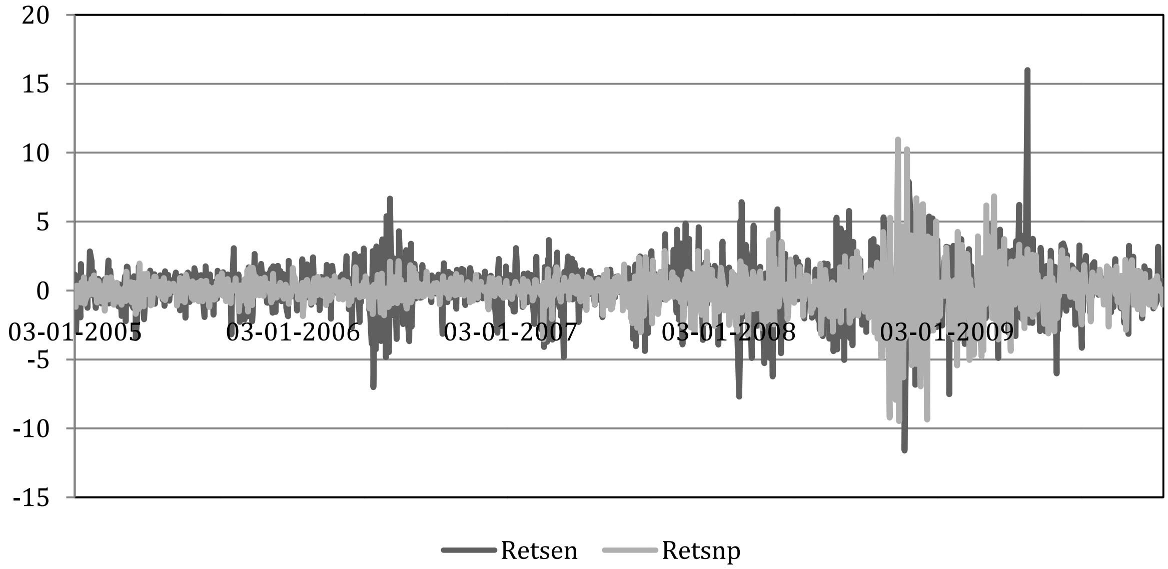

Figure 1: Graph of daily return on Sensex and S&P

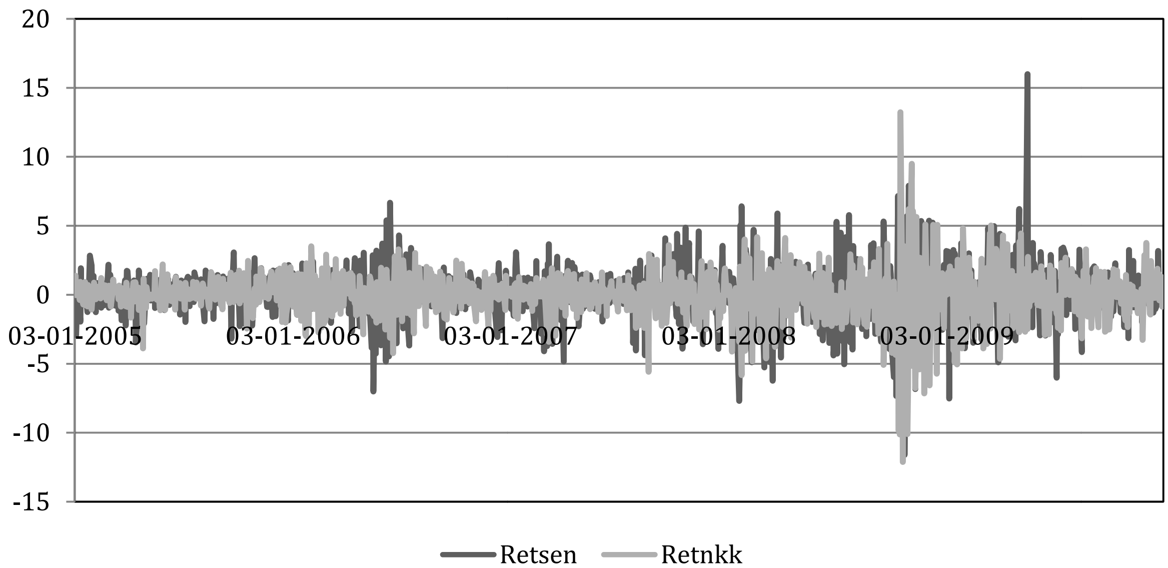

Figure 2: Graph of daily return on Sensex and Nikkei225

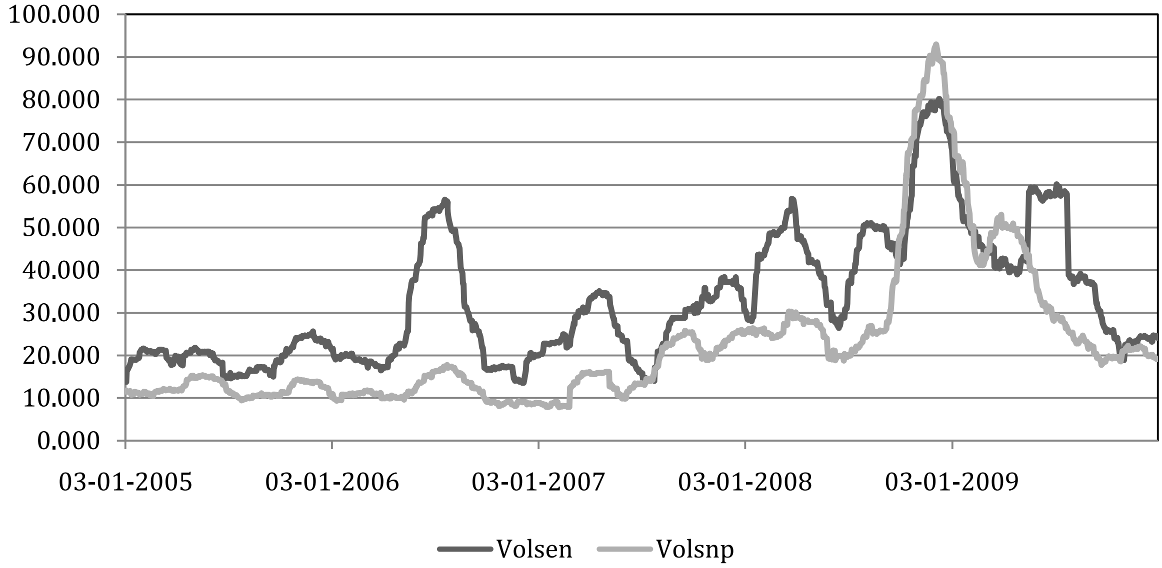

Figure 3: Graph of volatility of daily returns on Sensex and S&P

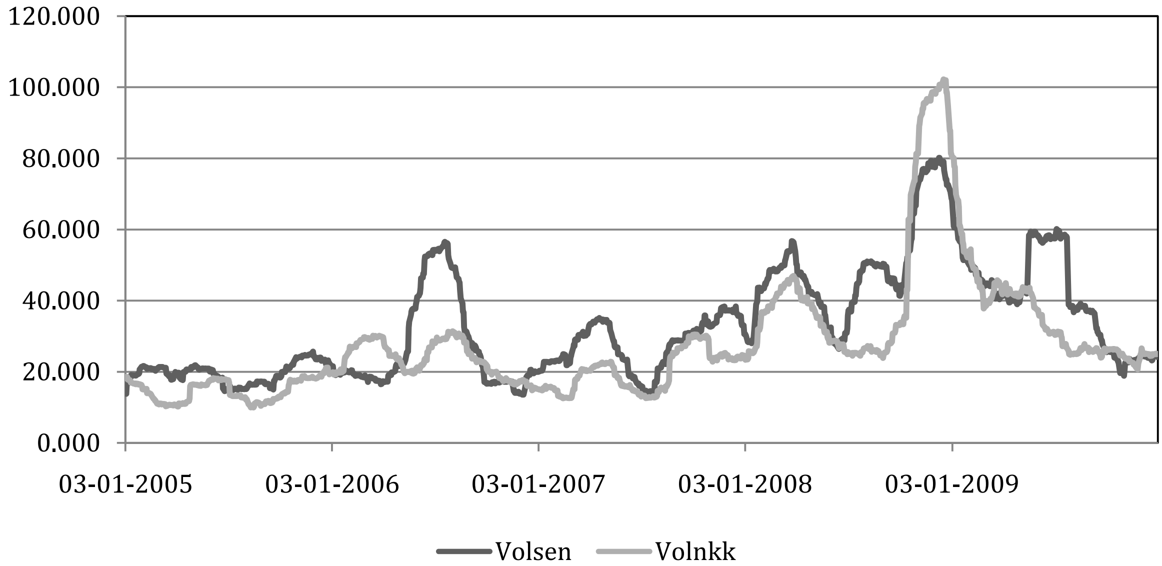

Figure 4: Graph of volatility of daily returns on Sensex and Nikkei225

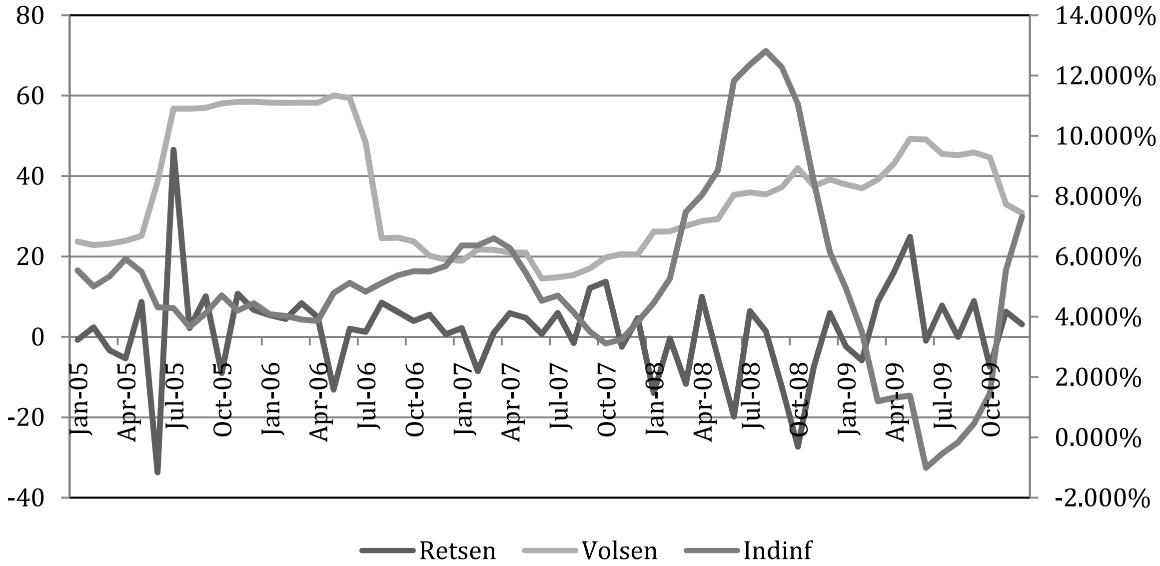

Figure 5: Graph of monthly returns, volatility and inflation for Sensex

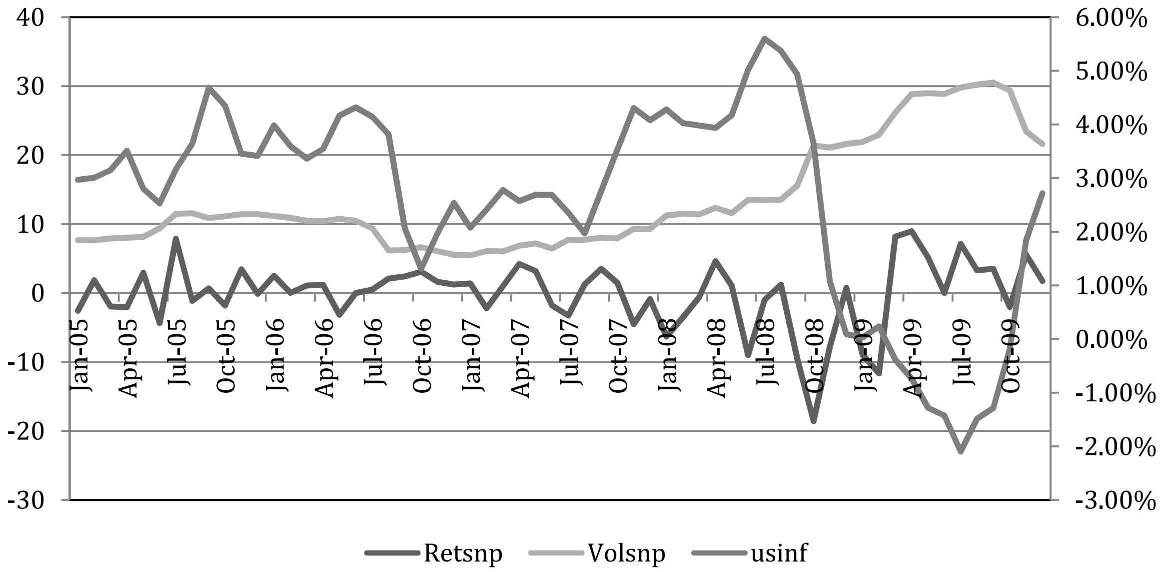

Figure 6: Graph of monthly returns, volatility and inflation for S&P

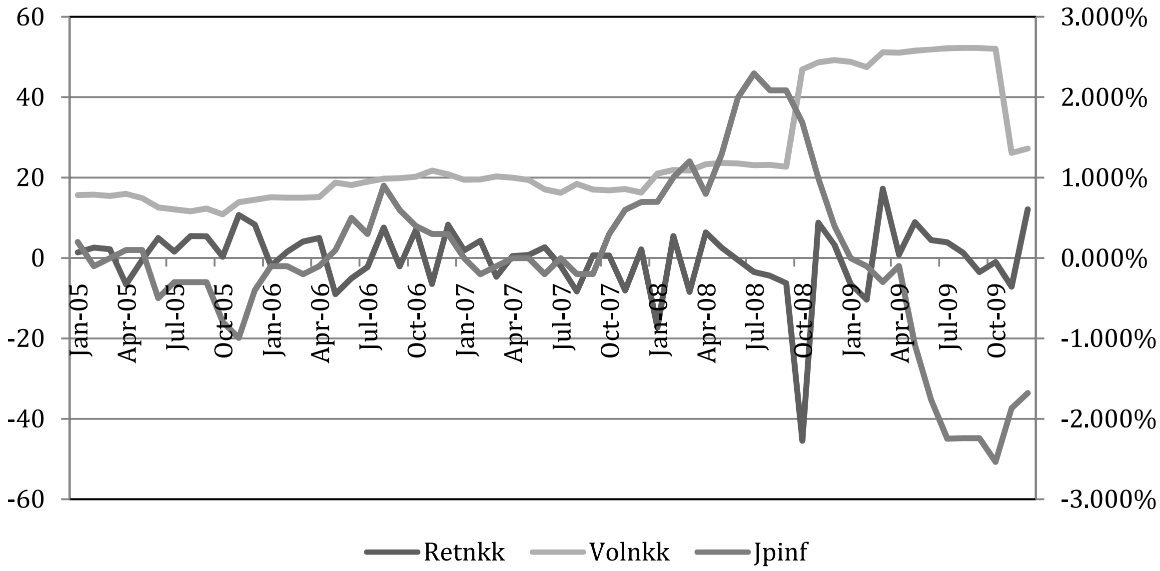

Figure 7: Graph of monthly returns, volatility and inflation for Nikkei

From the graphical analysis, we can see that there has been a significant shift in volatility levels after December 2007. The first news of financial institutions getting bust started coming out as early as January 2008 with AIG being the first. These incidents kept happening for the better part of 2008, with the major setback being, Lehman brothers going belly up. Thus, the period of 2005 to 2007 is taken to understand behaviour of capital markets before recession and the period of 2008 to 2009 is taken to understand the behaviour of markets post recession.

Results and Analysis

Test of contemporaneous volatility spillover between Sensex and S&P

In this section, we can analyze contemporaneous volatility spillover between India and USA. From table 2 we can see that δ_1 coefficient shows that there is no significant volatility spillover from USA. However, as we have discussed earlier that there is one day lag between India and USA. So, the existence of volatility spillover from USA capital market which affected Indian capital market should be subject to advance research by employing dynamic model. The result will be discussed later on.

Meanwhile, from table 3 we can extract that volatility of USA capital market is not affected from volatility spillover of Sensex . From testing of first model, we can conclude that there is no volatility spillover between USA and Indian capital market both pre-recession period and post recession period.

However, it is interesting to note that in the post recession period, the previous day return become statistically insignificant (for level of significance = 5%) in determining present day return.

Table 2: Result of processed data from equation (1) and (2), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
γ_0	-0.041544	-0.316885	-0.028388	-0.148728
γ_1	0.090798	2.174800	0.063755	1.311623
γ_2	0.160036	2.889944	0.391963	6.933713
γ_3	0.016684	1.706479	0.002061	0.348263
α_0	0.039067	1.302703	-0.088828	-0.901629
α_1	0.115752	5.510796	0.135067	4.587107
α_2	0.823674	25.515110	0.812787	21.562960
δ_1	0.005232	1.722136	0.012268	2.138149

Table 3: Result of processed data from equation (3) and (4) , Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-score	Value	Z-Score
θ_0	-0.036471	-0.529967	-0.049623	-0.239448
θ_1	-0.123143	-2.847798	-0.197384	-3.791932
θ_2	0.082884	4.409342	0.205026	6.276906
θ_3	0.002713	1.010074	0.001701	0.339276
β_0	0.015654	2.180277	-0.001838	-0.044276
β_1	0.056888	3.737308	0.091741	4.202666
β_2	0.910630	34.761610	0.897729	34.378450
Φ_1	0.000087	0.278828	0.000873	0.599420

Test of contemporaneous volatility spillover between Sensex and Nikkei

For the pre-recession period of 2005-2007, there was volatility spillover from Japanese capital markets to Sensex . However, this spillover was not significant in the post recession period of 2008-2009. For the Japanese capital market it is observed that previous day returns became significant only in the post recession period.

Table 4: Result of processed data from equation (1) and (2), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
γ_0	-0.169407	-1.230426	0.104242	0.453526
γ_1	0.080071	1.907028	0.053331	1.092605
γ_2	-0.007382	-0.161961	0.055292	1.137688
γ_3	0.018673	2.712984	-0.001183	-0.178301
α_0	0.084454	2.739194	-0.095806	-0.666870
α_1	0.112846	5.651388	0.147464	4.777687
α_2	0.838648	31.763020	0.823236	20.586860
δ_1	0.000180	0.142080	0.009736	1.389624

Table 5: Result of processed data from equation (1) and (2), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
θ_0	0.228946	2.128537	-0.179305	-0.644636
θ_1	0.002095	0.047006	-0.104283	-2.065412
θ_2	-0.005196	-0.226936	-0.001051	-0.037009
θ_3	-0.006659	-1.431707	0.003585	0.558723
β_0	-0.006428	-0.280609	0.071975	0.841636
β_1	0.094497	5.195824	0.137161	4.653833
β_2	0.862447	29.655440	0.818903	21.077180
Φ_1	0.002493	1.755695	0.002833	0.870515

Test of dynamic volatility spillover between Sensex and S&P

Previous day volatility was found to be significant in the post recession period, when considering spillover from USA to India, given that the previous day trading impacts trading Sensex today. It is interesting to note that where previous day return became significant only in post recession period for USA, previous day volatility was significant only in pre-recession period.

Table 6: Result of processed data from equation (5) and (6), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
η_0	-0.002081	-0.015706	-0.039353	-0.189116
η_1	0.054678	1.433382	-0.005663	-0.117724
η_2	0.499621	9.869871	0.283437	5.127445
η_3	0.012216	1.232930	0.002819	0.411089
χ_0	0.050256	1.637629	-0.242964	-1.585071
χ_1	0.110654	5.091310	0.134927	3.854870
χ_2	0.828251	24.486350	0.790752	15.111090
ω_1	0.003611	1.251171	0.021756	2.187564

Table 7: Result of processed data from equation (7) and (8), Sensex and S&P

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
ψ_0	-0.017348	-0.248520	-0.092995	-0.448725
ψ_1	-0.069299	-1.638579	-0.140260	-2.560772
ψ_2	-0.021721	-1.134953	0.025670	0.858541
ψ_3	0.002691	0.988180	0.002915	0.563601
ξ_0	0.015596	2.470477	-0.027864	-0.668453
ξ_1	0.053363	4.079671	0.091590	4.141417
ξ_2	0.919098	44.074280	0.897479	34.497870
ρ_1	-0.000003	-0.009138	0.001634	1.139945

Test of dynamic volatility spillover between Sensex and Nikkei

Dynamic volatility spillover from Japan to Sensex was only significant for pre-recession period after which it has become statistically insignificant. Also, Sensex volatility seems to dynamically impact Nikkei volatility in the pre-recession era. Hence, dynamic spillover effect existed between Sensex and Nikkei in bi-directional relationship.

Table 7: Result of processed data from equation (5) and (6), Sensex and NIkkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
η_0	-0.193799	-1.394306	0.112297	0.491427
η_1	0.079624	1.882445	0.047994	0.947391
η_2	0.009208	0.248297	0.054727	1.218343
η_3	0.019867	2.858414	-0.001511	-0.229622
χ_0	0.085420	2.722669	-0.087819	-0.580088
χ_1	0.113343	5.667895	0.155542	4.697133
χ_2	0.838018	31.566610	0.813992	18.584460
ω_1	0.000136	0.107504	0.009855	1.327765

Table 8: Result of processed data from equation (7) and (8), Sensex and Nikkei225

	2005-2007		2008-2009	
	Value	Z-Statistics	Value	Z-Statistics
ψ_0	0.210620	1.975067	-0.210391	-0.763466
ψ_1	0.003652	0.082072	-0.107616	-2.110110
ψ_2	0.049375	2.177348	0.076073	2.476572
ψ_3	-0.006171	-1.343571	0.004331	0.681940
ξ_0	-0.000447	-0.020356	0.080356	0.910576
ξ_1	0.093990	5.148870	0.143839	4.730969
ξ_2	0.867408	29.667760	0.816869	21.353140
ρ_1	0.002025	1.466252	0.002295	0.730578

Consolidated results

Contemporaneous spillover

		Sensex -S&P		S&P-Sensex		Sensex - Nikkei		Nikkei-Sensex	
		05-07	08-09	05-07	08-09	05-07	08-09	05-07	08-09
Contemporaneous	Constant							Sig.	
	Lagged Domestic Return	Sig.		Sig.	Sig.				Sig.
	Foreign Return	Sig.	Sig.	Sig.	Sig.				
	Foreign Volatility					Sig.			
	Variance Equation								
	Constant			Sig.		Sig.			
	Squared residual	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Lagged Domestic Volatility	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Foreign Volatility								

Dynamic spillover

		Sensex -S&P		S&P-Sensex		Sensex - Nikkei		Nikkei-Sensex	
		05-07	08-09	05-07	08-09	05-07	08-09	05-07	08-09
Dynamic	Constant								
	Lagged Domestic Return				Sig.	Sig.		Sig.	Sig.
	Foreign Return	Sig.	Sig.						Sig.
	Foreign Volatility					Sig.		Sig.	
	Variance Equation								
	Constant			Sig.	Sig.	Sig.			
	Squared residual	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Lagged Domestic Volatility	Sig.	Sig.	Sig.		Sig.	Sig.	Sig.	Sig.
	Foreign Volatility		Sig.						

Sig. = Significant with degree of significance of 5%

Greyed areas denote those parameters for which have changed their behaviour after recession

Conclusion

Contemporary volatility of the Japan capital markets influenced the Sensex in the pre-recession period in line with the first hypothesis. But in the post recession there was no significant (level of significance = 5%) contemporaneous spillover from USA and Japan capital markets to Sensex. However, US became a significant factor while considering dynamic spillover in the post recession era. Also, there was no bidirectional volatility spillover from India to US. But, the study showed evidence of dynamic volatility spillover from Indian market to Japanese Capital market.

There is considerable impact of the recession which is evident from the fact that various factors lost significance as determinants of returns and volatility in the considered capital markets. The factors which showed change in behaviour are:

Factors which became insignificant after recession:

- Lagged domestic return for Sensex , while examining the contemporaneous spillover effect with USA
- Impact of contemporaneous volatility spillover from Japan to India
- Lagged domestic volatility in US market, while examining dynamic spillover effects from Sensex
- Impact of dynamic volatility spillover from Japan to India

Factors which became significant only after recession (Modelling without inflation):

- Lagged domestic return for Japanese capital market while examining contemporaneous spillover effect of Indian capital markets
- Lagged domestic return for USA capital market while examining dynamic spillover effects of Sensex
- Impact of dynamic volatility spillover from USA to India

The probable economic fundamentals guiding the results could be several. The extent of Foreign Institutional Investments and Foreign Direct Investment which moves from one capital market to another capital market, given existing volatilities could explain the observed results. Also, there could be intermediate linkages between capital markets through other capital markets, instead of direct causal relationships. Additionally, the time zone differences could also be impacting the extent of correlation between capital markets. The investigation of these causes is beyond the scope of this work, and is a matter of future research.

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Appendix: Eviews Results

Results for equation (1) and (2), Sensex and S&P, 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:44
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 27 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.041544	0.131100	-0.316885	0.7513
RETSEN(-1)	0.090798	0.041750	2.174800	0.0296
RETSNP	0.160036	0.055377	2.889944	0.0039
VOLSNP	0.016684	0.009777	1.706479	0.0879
Variance Equation				
C	0.039067	0.029989	1.302703	0.1927
ARCH(1)	0.115752	0.021005	5.510796	0.0000
GARCH(1)	0.823674	0.032282	25.51511	0.0000
VOLSNP	0.005232	0.003038	1.722136	0.0850

R-squared	0.019298	Mean dependent var	0.142616
Adjusted R-squared	0.010394	S.D. dependent var	1.409945
S.E. of regression	1.402598	Akaike info criterion	3.308021
Sum squared resid	1516.775	Schwarz criterion	3.355857
Log likelihood	-1280.474	F-statistic	2.167332
Durbin-Watson stat	2.080899	Prob(F-statistic)	0.035080

Results for equation (1) and (2), Sensex and S&P, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:43
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 20 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.028388	0.190873	-0.148728	0.8818
RETSEN(-1)	0.063755	0.048608	1.311623	0.1896
RETSNP	0.391963	0.056530	6.933713	0.0000
VOLSNP	0.002061	0.005917	0.348263	0.7276
Variance Equation				
C	-0.088828	0.098520	-0.901629	0.3673
ARCH(1)	0.135067	0.029445	4.587107	0.0000
GARCH(1)	0.812787	0.037694	21.56296	0.0000
VOLSNP	0.012268	0.005738	2.138149	0.0325

R-squared	0.121484	Mean dependent var	-0.028751
Adjusted R-squared	0.109497	S.D. dependent var	2.476786
S.E. of regression	2.337255	Akaike info criterion	4.391283
Sum squared resid	2802.397	Schwarz criterion	4.456631
Log likelihood	-1135.929	F-statistic	10.13422
Durbin-Watson stat	2.184896	Prob(F-statistic)	0.000000

Results for equation (3) and (4), Sensex and S&P, 2005-2007

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 00:59
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 18 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.036471	0.068817	-0.529967	0.5961
RETSNP(-1)	-0.123143	0.043242	-2.847798	0.0044
RETSEN	0.082884	0.018797	4.409342	0.0000
VOLSEN	0.002713	0.002686	1.010074	0.3125
Variance Equation				
C	0.015654	0.007180	2.180277	0.0292
ARCH(1)	0.056888	0.015222	3.737308	0.0002
GARCH(1)	0.910630	0.026196	34.76161	0.0000
VOLSEN	8.67E-05	0.000311	0.278828	0.7804

R-squared	0.038018	Mean dependent var	0.025686
Adjusted R-squared	0.029284	S.D. dependent var	0.768137
S.E. of regression	0.756806	Akaike info criterion	2.165893
Sum squared resid	441.5944	Schwarz criterion	2.213729
Log likelihood	-835.6154	F-statistic	4.352933
Durbin-Watson stat	2.071881	Prob(F-statistic)	0.000096

Results for equation (3) and (4), Sensex and S&P, 2008-2009

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 04:44
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 24 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.049623	0.207238	-0.239448	0.8108
RETSNP(-1)	-0.197384	0.052054	-3.791932	0.0001
RETSEN	0.205026	0.032664	6.276906	0.0000
VOLSEN	0.001701	0.005014	0.339276	0.7344
Variance Equation				
C	-0.001838	0.041515	-0.044276	0.9647
ARCH(1)	0.091741	0.021829	4.202666	0.0000
GARCH(1)	0.897729	0.026113	34.37845	0.0000
VOLSEN	0.000873	0.001457	0.599420	0.5489

R-squared	0.140771	Mean dependent var	-0.052822
Adjusted R-squared	0.129047	S.D. dependent var	2.162954
S.E. of regression	2.018574	Akaike info criterion	3.837267
Sum squared resid	2090.290	Schwarz criterion	3.902614
Log likelihood	-991.6080	F-statistic	12.00674
Durbin-Watson stat	2.058531	Prob(F-statistic)	0.000000

Results for equation (1) and (2), Sensex and Nikkei, 2005-2007

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 00:46
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.169407	0.137682	-1.230426	0.2185
RETSEN(-1)	0.080071	0.041987	1.907028	0.0565
RETNKK	-0.007382	0.045577	-0.161961	0.8713
VOLNKK	0.018673	0.006883	2.712984	0.0067
Variance Equation				
C	0.084454	0.030832	2.739194	0.0062
ARCH(1)	0.112846	0.019968	5.651388	0.0000
GARCH(1)	0.838648	0.026403	31.76302	0.0000
VOLNKK	0.000180	0.001269	0.142080	0.8870

R-squared	0.009693	Mean dependent var	0.142616
Adjusted R-squared	0.000702	S.D. dependent var	1.409945
S.E. of regression	1.409450	Akaike info criterion	3.315838
Sum squared resid	1531.630	Schwarz criterion	3.363674
Log likelihood	-1283.519	F-statistic	1.078073
Durbin-Watson stat	2.025172	Prob(F-statistic)	0.375458

Results for equation (1) and (2), Sensex and Nikkei, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:45
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.104242	0.229849	0.453526	0.6502
RETSEN(-1)	0.053331	0.048811	1.092605	0.2746
RETNKK	0.055292	0.048600	1.137688	0.2553
VOLNKK	-0.001183	0.006637	-0.178301	0.8585
Variance Equation				
C	-0.095806	0.143666	-0.666870	0.5049
ARCH(1)	0.147464	0.030865	4.777687	0.0000
GARCH(1)	0.823236	0.039988	20.58686	0.0000
VOLNKK	0.009736	0.007006	1.389624	0.1646

R-squared	-0.002170	Mean dependent var	-0.028751
Adjusted R-squared	-0.015845	S.D. dependent var	2.476786
S.E. of regression	2.496331	Akaike info criterion	4.500146
Sum squared resid	3196.845	Schwarz criterion	4.565493
Log likelihood	-1164.288	Durbin-Watson stat	2.010762

Results for equation (3) and (4), Sensex and Nikkei, 2005-2007

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 01:01
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 21 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.228946	0.107560	2.128537	0.0333
RETNKK(-1)	0.002095	0.044569	0.047006	0.9625
RETSEN	-0.005196	0.022894	-0.226936	0.8205
VOLSEN	-0.006659	0.004651	-1.431707	0.1522
		Variance Equation		
C	-0.006428	0.022906	-0.280609	0.7790
ARCH(1)	0.094497	0.018187	5.195824	0.0000
GARCH(1)	0.862447	0.029082	29.65544	0.0000
VOLSEN	0.002493	0.001420	1.755695	0.0791

R-squared	0.001881	Mean dependent var	0.042037
Adjusted R-squared	-0.007181	S.D. dependent var	1.076763
S.E. of regression	1.080623	Akaike info criterion	2.869258
Sum squared resid	900.3317	Schwarz criterion	2.917094
Log likelihood	-1109.576	F-statistic	0.207567
Durbin-Watson stat	1.995385	Prob(F-statistic)	0.983784

Results for equation (3) and (4), Sensex and Nikkei, 2008-2009

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 04:47
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 39 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.179305	0.278149	-0.644636	0.5192
RETNKK(-1)	-0.104283	0.050490	-2.065412	0.0389
RETSEN	-0.001051	0.028396	-0.037009	0.9705
VOLSEN	0.003585	0.006417	0.558723	0.5764
		Variance Equation		
C	0.071975	0.085519	0.841636	0.4000
ARCH(1)	0.137161	0.029473	4.653833	0.0000
GARCH(1)	0.818903	0.038853	21.07718	0.0000
VOLSEN	0.002833	0.003254	0.870515	0.3840

R-squared	0.008336	Mean dependent var	-0.074556
Adjusted R-squared	-0.005195	S.D. dependent var	2.342794
S.E. of regression	2.348872	Akaike info criterion	4.165487
Sum squared resid	2830.323	Schwarz criterion	4.230834
Log likelihood	-1077.109	F-statistic	0.616057
Durbin-Watson stat	1.988734	Prob(F-statistic)	0.742834

Results for equation (5) and (6), Sensex and S&P, 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:45
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 26 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.002081	0.132495	-0.015706	0.9875
RETSEN(-1)	0.054678	0.038146	1.433382	0.1517
RETSNP(-1)	0.499621	0.050621	9.869871	0.0000
VOLSNP(-1)	0.012216	0.009908	1.232930	0.2176
		Variance Equation		
C	0.050256	0.030688	1.637629	0.1015
ARCH(1)	0.110654	0.021734	5.091310	0.0000
GARCH(1)	0.828251	0.033825	24.48635	0.0000
VOLSNP(-1)	0.003611	0.002886	1.251171	0.2109

R-squared	0.116207	Mean dependent var	0.142616
Adjusted R-squared	0.108183	S.D. dependent var	1.409945
S.E. of regression	1.331496	Akaike info criterion	3.225729
Sum squared resid	1366.892	Schwarz criterion	3.273564
Log likelihood	-1248.421	F-statistic	14.48238
Durbin-Watson stat	2.107259	Prob(F-statistic)	0.000000

Results for equation (5) and (6), Sensex and S&P, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:43
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 18 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.039353	0.208088	-0.189116	0.8500
RETSEN(-1)	-0.005663	0.048104	-0.117724	0.9063
RETSNP(-1)	0.283437	0.055278	5.127445	0.0000
VOLSNP(-1)	0.002819	0.006858	0.411089	0.6810
		Variance Equation		
C	-0.242964	0.153283	-1.585071	0.1130
ARCH(1)	0.134927	0.035002	3.854870	0.0001
GARCH(1)	0.790752	0.052329	15.11109	0.0000
VOLSNP(-1)	0.021756	0.009945	2.187564	0.0287

R-squared	0.041309	Mean dependent var	-0.028751
Adjusted R-squared	0.028228	S.D. dependent var	2.476786
S.E. of regression	2.441579	Akaike info criterion	4.442022
Sum squared resid	3058.150	Schwarz criterion	4.507370
Log likelihood	-1149.147	F-statistic	3.157822
Durbin-Watson stat	2.111861	Prob(F-statistic)	0.002809

Results for equation (7) and (8), Sensex and S&P, 2005-2007

Dependent Variable: RETSNP
Method: ML - ARCH
Date: 03/03/10 Time: 01:00
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 25 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.017348	0.069804	-0.248520	0.8037
RETSNP(-1)	-0.069299	0.042292	-1.638579	0.1013
RETSEN(-1)	-0.021721	0.019138	-1.134953	0.2564
VOLSEN(-1)	0.002691	0.002723	0.988180	0.3231
Variance Equation				
C	0.015596	0.006313	2.470477	0.0135
ARCH(1)	0.053363	0.013080	4.079671	0.0000
GARCH(1)	0.919098	0.020853	44.07428	0.0000
VOLSEN(-1)	-2.61E-06	0.000286	-0.009138	0.9927

R-squared	0.015725	Mean dependent var	0.025686
Adjusted R-squared	0.006789	S.D. dependent var	0.768137
S.E. of regression	0.765525	Akaike info criterion	2.185864
Sum squared resid	451.8279	Schwarz criterion	2.233700
Log likelihood	-843.3940	F-statistic	1.759711
Durbin-Watson stat	2.070493	Prob(F-statistic)	0.092322

Results for equation (7) and (8), Sensex and S&P, 2008-2009

Dependent Variable: RETSNP
Method: ML – ARCH
Date: 03/03/10 Time: 04:45
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 22 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.092995	0.207243	-0.448725	0.6536
RETSNP(-1)	-0.140260	0.054773	-2.560772	0.0104
RETSEN(-1)	0.025670	0.029900	0.858541	0.3906
VOLSEN(-1)	0.002915	0.005172	0.563601	0.5730
Variance Equation				
C	-0.027864	0.041685	-0.668453	0.5038
ARCH(1)	0.091590	0.022116	4.141417	0.0000
GARCH(1)	0.897479	0.026015	34.49787	0.0000
VOLSEN(-1)	0.001634	0.001433	1.139945	0.2543

R-squared	0.017717	Mean dependent var	-0.052822
Adjusted R-squared	0.004313	S.D. dependent var	2.162954
S.E. of regression	2.158284	Akaike info criterion	3.912222
Sum squared resid	2389.652	Schwarz criterion	3.977569
Log likelihood	-1011.134	F-statistic	1.321797
Durbin-Watson stat	2.051613	Prob(F-statistic)	0.237608

Results for equation (5) and (6), Sensex and Nikkei 2005-2007

Dependent Variable: RETSEN
Method: ML - ARCH
Date: 03/03/10 Time: 00:47
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 23 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.193799	0.138993	-1.394306	0.1632
RETSEN(-1)	0.079624	0.042298	1.882445	0.0598
RETNKK(-1)	0.009208	0.037085	0.248297	0.8039
VOLNKK(-1)	0.019867	0.006950	2.858414	0.0043
Variance Equation				
C	0.085420	0.031374	2.722669	0.0065
ARCH(1)	0.113343	0.019997	5.667895	0.0000
GARCH(1)	0.838018	0.026548	31.56661	0.0000
VOLNKK(-1)	0.000136	0.001263	0.107504	0.9144

R-squared	0.010560	Mean dependent var	0.142616
Adjusted R-squared	0.001576	S.D. dependent var	1.409945
S.E. of regression	1.408833	Akaike info criterion	3.314632
Sum squared resid	1530.289	Schwarz criterion	3.362468
Log likelihood	-1283.049	F-statistic	1.175475
Durbin-Watson stat	2.025108	Prob(F-statistic)	0.314338

Results for equation (5) and (6), Sensex and Nikkei, 2008-2009

Dependent Variable: RETSEN
Method: ML – ARCH
Date: 03/03/10 Time: 04:46
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 30 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.112297	0.228511	0.491427	0.6231
RETSEN(-1)	0.047994	0.050659	0.947391	0.3434
RETNKK(-1)	0.054727	0.044919	1.218343	0.2231
VOLNKK(-1)	-0.001511	0.006583	-0.229622	0.8184
Variance Equation				
C	-0.087819	0.151388	-0.580088	0.5619
ARCH(1)	0.155542	0.033114	4.697133	0.0000
GARCH(1)	0.813992	0.043800	18.58446	0.0000
VOLNKK(-1)	0.009855	0.007422	1.327765	0.1843

R-squared	0.001558	Mean dependent var	-0.028751
Adjusted R-squared	-0.012066	S.D. dependent var	2.476786
S.E. of regression	2.491684	Akaike info criterion	4.500572
Sum squared resid	3184.955	Schwarz criterion	4.565919
Log likelihood	-1164.399	F-statistic	0.114322
Durbin-Watson stat	1.981187	Prob(F-statistic)	0.997408

Results for equation (7) and (8), Sensex and Nikkei, 2005-2007

Dependent Variable: RETNKK
Method: ML - ARCH
Date: 03/03/10 Time: 01:02
Sample(adjusted): 2 780
Included observations: 779 after adjusting endpoints
Convergence achieved after 21 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	0.210620	0.106639	1.975067	0.0483
RETNKK(-1)	0.003652	0.044495	0.082072	0.9346
RETSEN(-1)	0.049375	0.022677	2.177348	0.0295
VOLSEN(-1)	-0.006171	0.004593	-1.343571	0.1791
	Variance Equation			
C	-0.000447	0.021943	-0.020356	0.9838
ARCH(1)	0.093990	0.018255	5.148870	0.0000
GARCH(1)	0.867408	0.029237	29.66776	0.0000
VOLSEN(-1)	0.002025	0.001381	1.466252	0.1426

R-squared	0.009968	Mean dependent var	0.042037
Adjusted R-squared	0.000980	S.D. dependent var	1.076763
S.E. of regression	1.076236	Akaike info criterion	2.866360
Sum squared resid	893.0365	Schwarz criterion	2.914196
Log likelihood	-1108.447	F-statistic	1.109011
Durbin-Watson stat	2.000112	Prob(F-statistic)	0.355223

Results for equation (7) and (8), Sensex and Nikkei, 2008-2009

Dependent Variable: RETNKK
Method: ML – ARCH
Date: 03/03/10 Time: 04:47
Sample(adjusted): 2 522
Included observations: 521 after adjusting endpoints
Convergence achieved after 37 iterations

	Coefficient	Std. Error	z-Statistic	Prob.
C	-0.210391	0.275574	-0.763466	0.4452
RETNKK(-1)	-0.107616	0.051000	-2.110110	0.0348
RETSEN(-1)	0.076073	0.030717	2.476572	0.0133
VOLSEN(-1)	0.004331	0.006351	0.681940	0.4953
	Variance Equation			
C	0.080356	0.088248	0.910576	0.3625
ARCH(1)	0.143839	0.030404	4.730969	0.0000
GARCH(1)	0.816869	0.038255	21.35314	0.0000
VOLSEN(-1)	0.002295	0.003141	0.730578	0.4650

R-squared	0.010862	Mean dependent var	-0.074556
Adjusted R-squared	-0.002635	S.D. dependent var	2.342794
S.E. of regression	2.345879	Akaike info criterion	4.155538
Sum squared resid	2823.114	Schwarz criterion	4.220885
Log likelihood	-1074.518	F-statistic	0.804762
Durbin-Watson stat	1.994800	Prob(F-statistic)	0.583569